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IRON IN THE GROUND WATER SUPPLIES OF MASSACHUSETTS

BY CLARENCE I. STERLING, JR.,* AND JOHN B. BELKNAP†

(Presented at a meeting of the Sanitary Section of the Boston Society of Civil Engineers, December 2, 1931)

At the end of 1930 there were 236 municipalities out of the 355 cities and towns in the State supplied with water from a public water supply system, and of this number, 89 were supplied entirely from ground water sources and 21 were supplied from a combination of surface and ground water sources. The total population of the State, according to the census of 1930, was 4,249,614, about 97 per cent of which were living in municipalities having a public water supply. About 20 per cent of the population supplied with water from a public source were provided from ground water sources. The largest municipality in this State, which is supplied entirely from a ground water source, is the city of Lowell, where the water consumption amounts to nearly 6,000,000 gallons per day. For the most part, ground water supplies are used by the smaller municipalities.

Ground water supplies in glacial deposits are generally the most suitable sources of supply for the small towns, as it is not difficult to protect them from pollution, and the expense of such protection is small. Many of the small towns are located along streams into which sewage or industrial wastes are discharged, making it impossible to obtain a water supply from such a source without the installation of a treatment plant, while in other towns a surface supply cannot be made available except at considerable expense, making it necessary for

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these towns to resort to the use of ground water. In general, ground water supplies are of better quality than surface supplies, and ordinarily contain no objectionable bacteria if care is taken in locating the collecting works remote from sources of pollution. In a ground water supply, assuming that the source of supply is located in an unpolluted territory, the three most objectionable qualities found in the water from the standpoint of the consumer are iron, hardness and a high carbonic acid content. This discussion will be confined to the occurrence of iron in the ground water supplies of the State.

The reason for the occurrence of iron in ground waters is quite well known. Rain water, which is saturated with dissolved oxygen when it reaches the ground, percolates through the soil, and in coming in contact with organic matter much of the oxygen is exhausted in oxidizing this organic matter and carbonic acid is taken up by the water. Many water-bearing soils, such as sand and gravel, contain various amounts of iron, so that when water containing free carbonic acid and little dissolved oxygen comes in contact with the iron in the soil iron is taken into solution. The same thing often happens when surface water, such as river water, containing a large quantity of organic matter, percolates through the ground into a well or filter gallery. A water having a high iron content is not necessarily devoid of dissolved oxygen, as the water in the source of supply may come from several different strata, some of these strata containing little or no organic matter to exhaust the supply of dissolved oxygen.

The deterioration of ground water supplies in this State is not common, as a great majority of these supplies have been in use for years without any marked change in the quality of the water. All ground water supplies in the State, however, contain more or less iron, but the supplies in certain sections of the easterly and the northeasterly parts of the State experience the greatest trouble from large quantities of iron. The supplies which have been affected by an objectionable quantity of iron in the water are as follows:

Amesbury — tubular wells.

Ayer — tubular wells.

Billerica — tubular wells.

Brookline — wells.

Cohasset — well at Beechwood Station.

Lowell — boulevard wells.

Marblehead — wells.

Methuen — wells at Harris Brook.

Middleborough — dug well.

Norwood — tubular wells.

Reading — filter gallery.

Waltham — old dug well.

Winchendon — old wells.

This study has been based upon the results of the analyses of samples collected by various local water department officials, and in

some cases the high iron content shown by the samples analyzed may be due to improper collection.

At the present time there are seven municipalities in the State having deferrization plants, namely, Amesbury, Brookline, Cohasset, Lowell, Marblehead, Middleborough and Reading. The treatment at the Amesbury, Brookline, Lowell and Middleborough plants consists of aeration, coke filtration, and sedimentation, which is followed by sand filtration. In Reading the water from the filter gallery near the Ipswich River is treated by using alum and lime in a coagulation process, which is followed by sedimentation and rapid sand filtration. At the Marblehead plant the treatment consists of aeration, sedimentation and slow sand filtration. At the Cohasset plant the treatment has generally been aeration, coke filtration, sedimentation and mechanical sand filtration, but recently the Cohasset Water Company has been experimenting in an effort to increase the efficiency of their filters by the use of coagulants. These plants have generally been efficient in reducing the iron content of the water to an amount which is not objectionable to the consumer.

It is noticeable that iron generally occurs where the sources of supply are located in swampy areas. In these areas there is generally found a stratum of peat or some other soil that is high in organic matter. As stated before, the organic matter through a process of decomposition exhausts the dissolved oxygen in the water and causes carbonic acid to take its place.

The city of Waltham is supplied by two large dug wells, one located on the Stony Brook watershed immediately above the point where Stony Brook enters the Charles River, and the other, which is the original source of supply, located 35 feet from the Charles River. The old supply is high in iron, while the new well contains comparatively little iron. The practice of the Water Department is to pump equal amounts of water from each well, the mixed water being sufficiently low in iron to cause few complaints from the consumers in that city.

In the case of Reading there are two sources of supply, — the original source, a filter gallery near the Ipswich River, the water from which is high in iron, and the new source, which consists of tubular wells located some distance back from the river, which are low in iron. It is necessary for the town to treat the water from the filter gallery before it is pumped into the distribution mains.

In Billerica many complaints have been made relative to the objectionable quantity of iron in the water, but it has been noticed that the water from the old tubular wells, which are nearer to the Concord River than the new wells, contains a larger quantity of iron than the latter.

When it is desired to install a ground water supply it is necessary to determine the quality and quantity of the water available. This can be done by installing test wells on the site selected and making an analysis of the water pumped from the wells. In order to foretell the future quality and quantity of water available it is necessary to make a continuous pumping test on the wells often for a period of from one to three weeks. Observations should be made on the height of ground water, rate of pumping, and samples collected regularly for analysis. The value of the analyses of water taken at regular intervals during a continuous pumping test is greater than that of a single sample from a test well, as they give a history of the chemical condition of the water as affected by the test. In a continuous test the ground water table is lowered, which tends to cause a flow of water from areas that are not immediately tributary to the wells, thus bringing in water of different quality. A lowering of the water table may also draw water from any near-by surface source of supply, and possibly cause a deterioration in the quality of the water.

Free ammonia, being a product of decay, gives a good indication of the amount of organic matter in the water. In this process of decomposition carbonic acid is given off so that the free ammonia often varies directly with the iron content of the water. It has been observed when a pumping test has been made on a group of wells as a source of water supply that in instances where the free ammonia content in the water increases during the test, and although the iron content of the water was low, after the supply had been in use a number of years the quantity of iron has increased to such an extent as to make treatment of the water desirable.

There are several other factors which influence more or less the amount of iron in ground water supplies, such as rainfall, the height of the ground water table, and the amount of pumping upon the wells, but there does not appear to be any direct relationship between any one of these factors and the amount of iron in the water.

One of the most common causes for the increase in the iron content is excessive pumping on the source of supply, the exact influence of which is not clearly apparent. This is illustrated by the deterioration of the quality of water from a source of supply in the eastern portion of the State. This supply consists of a group of 2½-inch driven wells. The quality of the water, as shown by the analyses of samples collected at regular intervals during the preliminary pumping test, was satisfactory for water supply purposes, being clear, colorless, soft and low in organic matter and iron. The water from this supply was pumped

into the distribution mains at the rate of 20 gallons per minute per well, which is a higher rate of pumping than driven wells of this size should be subjected to. The wells were driven in fairly fine material, so this rate of pumping resulted in the clogging of a number of the wells. As the amount of water pumped from the wells remained the same, the clogging of some of the wells resulted in an increased draft upon the remaining wells. Consequently the iron content of the water increased rapidly to such a point that it became objectionable to the consumer.

The dug well at the Beechwood Station of the Cohasset Water Company is an example of the care that is needed to properly interpret the results of a pumping test made upon a ground water supply. In 1907 the Cohasset Water Company located several driven wells and one dug test well in a swamp in the Beechwood section of the town. The dug well was pumped continuously for a period of seven days at a rate of 300,000 gallons per day. The analyses showed that the amount of iron in the water varied from .85 to 1.90 parts per million, while the free ammonia varied from .044 to .074 parts per million. As a result of the test the well was abandoned. Several other test wells were driven in this locality and iron was encountered at all locations. Finally, in 1908, a new test well was sunk about 90 feet south of the dug well which had proven unsatisfactory in the previous pumping test. No iron was encountered in the sinking of this well, and it appeared that the well was located in the only part of the entire area that was free from iron. A pumping test was made upon this well in 1908, and the well was pumped continuously for a period of seven days at the rate of 260,000 gallons per day. During the pumping test the water pumped was discharged upon the ground in the swamp surrounding the well, so that in all probability much of this water recirculated through the well during the test. When the water from the well was eventually pumped into the distribution mains off the watershed of the well the iron content increased rapidly, as the ground water table was lowered in the vicinity, which resulted in drawing water from greater distances where the soil was permeated with iron. The quality of this water continued to deteriorate until it was necessary for the Cohasset Water Company to install a deferrization plant in 1913.

There are a number of instances which bear out the value of a continuous pumping test upon a group of test wells, and one of the best examples of these is in the case of Georgetown. Test wells have been located at a number of places throughout the town, but in all cases a high iron content in the ground water has been found. In 1926 the hopes of the Water Supply Committee of that town were raised by

the fact that the analysis of samples of water collected on several occasions from a test well near West Street showed an iron content of only .15 part per million. Several additional wells were driven in this locality, and a continuous pumping test was made upon this group of wells for a period of six days, and the average iron content of the water during this test was 1.49 parts per million. As a result it was found that these wells could not be used as a source of supply unless the water was treated. If this relatively inexpensive pumping test had not been made, the town might have installed an expensive water supply system, the water from which would have been unsatisfactory for use.

Billerica is another town troubled with a high content of iron in its water supply; in fact, the iron content of the supply is probably higher than in any other town without a deferrization plant. The water supply for this town is obtained from a group of tubular wells near the Concord River, which were installed in 1897. From the very beginning the water contained a considerable quantity of iron, and additional wells have been installed from time to time, but no relief has been obtained. In 1929 a small experimental deferrization plant was built in this town, but the experimental work has not been carried out satisfactorily at this plant, as it is only used for short periods of time and few tests are made to determine the efficiency of the filter or the quantity of water passing through it. Unless a new source of supply is installed or a deferrization plant constructed the town will continue to experience much trouble from iron.

In the cases we have discussed the common causes for the increase of iron in ground water has been shown. An example will now be given showing how the decrease in the iron content was brought about in one town.

The North Chelmsford Fire District in the town of Chelmsford installed a group of twenty $2\frac{1}{2}$ -inch tubular wells near Newfield Pond in 1908, and much trouble was experienced from the objectionable amount of iron in the water. At times this iron content became as high as 3 parts per million. Finally, in 1922, a group of ten additional $2\frac{1}{2}$ -inch wells were installed. This resulted in a lower draft upon each well, and the iron content of the water pumped was reduced materially until in the year 1930 it averaged only .24 part per million.

If a city or town has been troubled with an objectionable amount of iron in the water there are several courses it may pursue to alleviate this condition. One is to install additional wells on the same site to reduce the draft on each of the individual wells. Another, which will often help, is to clean out the wells in the event that some of the wells

having become clogged will cause an increased draft on the remainder of the wells. This excessive draft will often result in a higher iron content. Another common method of reducing the high content of the water pumped into the distribution system is to locate a new source of supply, which can be used in conjunction with the original source, resulting in a smaller amount of iron in the mixed water. If it is found, after a careful study has been made, that none of the above remedies can be successfully used, it will be necessary to either abandon the source of supply or to install a suitable deferrization plant.

Experience has shown that proper care is essential in the selection of a site for the source of supply, and an adequate pumping test with a sufficient number of analyses should be made of the water in order to determine the probable character of the water which the source may be expected to furnish over a long period. Care should also be taken that sufficient additional wells are installed from time to time to provide for increased consumption in order that the draft on a particular group of wells may not be excessive.

Within the past month complaints have been received by the Massachusetts Department of Public Health, from several small towns having ground water supplies, relative to the increase in the iron content of the water supplied. As all of these complaints were received at approximately the same time the question arises as to whether or not this increase in iron may not be due to the effects of the 1930 drought. At the present time the cause for this increased iron content has not been established. It is evident, however, that the drought of 1930 had a far-reaching effect upon the ground water supplies in this State, and in certain portions of the State the ground water table has not recovered to the elevation it held in the spring of 1929.

Discussion

MR. KINGSBURY:* I talked with Mr. Arthur D. Weston, chief engineer, just before coming out, and he wanted me to call attention to the fact that one shouldn't be too easily discouraged in searching for a water supply. At Wilmington they searched all through the south-westerly part of the town—in fact, pretty much all over the town in sections that seemed to fall within the old bed of the Merrimack River and which geologists say came down in this direction at one time. Only when they tried in the northerly part of the town did they strike soil which yielded water free from iron. Those troubles that have come

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in to us recently — complaints and requests for analysis and search through the system to see where the iron originates — are going to be very interesting to study. Preliminary indications are that in one or two cases trouble occurs not so much from iron at the source as from iron picked up in the distribution system, due to the high carbonic acid quality of the water pumped from the wells.

QUESTION: Hasn't there been some trouble with iron at Provincetown?

MR. PAUL F. HOWARD: * The troubles at Provincetown are old and historic, but one finds particular evidence of it in cleaning the mains today. Some years ago Provincetown secured its supply of water right in the town in that section people call "Blown-up," which they think was blown up from the seas. While the iron content was very high and increased with the years, they went on with heavier and heavier drafts. They had at that time shallow wells, so they thought they would go deeper. They drove a well 416 feet deep. Of course, after they got down around 200 feet they began to get brackish water with a heavy chlorine content. At 204 feet they hit a good gravel stratum, they tell me, in which they found particles of organic matter, or seaweed. Perhaps one shouldn't take this statement at its full weight, but they claimed they found particles of seaweed 204 feet down, which apparently had been there a long time. Then they continued digging and carried the well down to 416 feet.

In cleaning the mains in town the usual tuberculation is found, but there are also deposits of iron in the mains. In fact, the main inside looks a good deal like a sluggish sewer. In an 8-inch main there will be 3 to 4 inches in depth of iron deposit in the bottom, more or less granular in substance. There is not the usual tuberculation around the mains, but out beyond the town in that section, which is not supplied by that original supply, the mains haven't this deposit in them, but just the tuberculation.

Provincetown went farther out into Truro, to what might be called the mainland, into the lateral moraine which stretches from Truro to Chatham, and secured a good supply, but I notice that now the chlorine content of the water is increasing and the iron content is increasing, possibly caused by the heavier draft during the summer months when they have been pumping twenty-two to twenty-four hours a day. The Cape is narrow at that point and one would expect to get the influence of the sea on both sides with continuous hard draft. Personally, I feel that Provincetown will have to go still farther up the

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Cape to secure more water, rather than pump the section hard where they are.

MR. JOHN F. PIERCE: * At any of these places where there has been trouble from iron did they use the air lift for pumping? Would that make any difference in the iron content?

MR. ALMON L. FALES: † The air might tend to precipitate the iron.

PROF. GORDON M. FAIR: ‡ One method of treatment for excessive iron content is the introduction of air. Where the air lift is used it introduces aeration and causes precipitation. I should say the iron content would be greatly reduced by the use of the air lift. Whenever iron in ground water is mentioned it reminds me of one of the first jobs I went out on, in which a factory in the vicinity of Washington, D. C., had suddenly experienced a very rapid increase in the iron content of its water, with the development of *Crenothrix* in the water and clogging of the pipes in the industrial water supply system. This industry is now defunct. It was a brewery, so you see it was a good many years ago. The question was, just what was responsible for this condition. The water had been very good for a great many years and suddenly it went bad. I discovered after a time that the owners of the factory had destroyed the quality of their own water supply by using the catchment area adjacent to the source of supply as a dumping ground for the spent wort of the factory. This spent wort was undergoing active decomposition and giving off very active carbon dioxide, and the water had been carrying this material deep down into the ground and thus making the iron soluble. It has increased the carbon dioxide content of the water over 100 p. p. m., and with it increased the iron content of the water.

At the same time, they were also discharging some acid liquors on the ground, and these also helped matters along and increased the iron content. After removing these dumps of spent wort, and allowing the rain to soak through for a good many months, the trouble cleared up and the water returned to its former condition.

MR. GEORGE G. BOGREN: § I might add the case of a water supply in Massachusetts which bears out the same experience. In this place they draw water from a filter gallery and tubular wells. The gallery water in the spring of the year, when the meadows become flooded, usually has a high iron content, but as the water level lowers so that

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the filter gallery is pulling ground water, the iron content drops. This spring they had a particularly bad case, and we think it was due to the fact that the ground water table was lowered so much last year that there was a greatly induced current of surface water coming in from above. The water from the filter gallery had an iron content of 2 to 5 p. p. m., and the water from the tubular wells the same amount. That condition existed for about two months. The water in the mains was clear, and there was no evident precipitation of iron. Even after adding lime and letting it stand from three weeks to a month, the water showed no precipitate of iron. That seems to indicate that in organic solution the iron is hard to remove, but in mineral combination it is easily removed.

MR. KINGSBURY: I was asked the other day whether I knew of any extensive stripping of well field areas; whether that would help? Perhaps you know of such an experience.

PROFESSOR FAIR: The stripping would have to be done on the entire catchment area. In connection with that I remember in Frankfurt, Germany, where they were trying to increase the yield of the wells, I believe Lindley was responsible for using the water from the Main River which was heavily polluted, and pumping it on to the catchment area of the wells. It was first filtered through slow sand filters and then pumped on to the well area. Then they tried the method of not placing the water on the surface of the ground but building a charging gallery into which this water from the filters passes 8 or 10 feet underground and then passes to a ground water stratum, so that it does not come into the zone of what Sedgwick terms the "living earth" in which you have this intake of carbon dioxide. They have never had an increase in the iron content.

MR. KINGSBURY: To what extent do they filter the water?

PROFESSOR FAIR: The water is very badly polluted, practically dilute sewage, but there is no iron in the river water. The iron is in the soil, but there is no carbon dioxide in the water as it flows through.

MR. ALFRED O. DOANE: * In Newton we have an instance where there is quite a large catchment area, the surface of which has been stripped and the soil taken for filling the Back Bay. This was right over the area from which Newton draws its water supply in Needham. The whole country was denuded, and the hills leveled down over hundreds of acres. Yet Newton has as much trouble with CO_2 as any place around here. I have lived there a great many years. I was concerned with making the surveys for that plant and in putting it in, and it has been

* Senior Mechanical Engineer, Metropolitan District Commission.

rather surprising to me to have so much trouble with iron. The water looks all right, but we had to do extensive cleaning out of the filter gallery. It was a wooden gallery and there were troubles with it. At that time City Engineer Noyes, who was in charge of the work, had just learned about Crenothrix, and he was greatly concerned because he feared that the wooden gallery might be conducive to the growth of Crenothrix, and he wondered what was going to happen. It turned out there was plenty of Crenothrix in there. The gallery was all hung with strands and cobwebs of it. The water used to be just about like tomato cocktails, especially when a spasm of running the hose would come during the summer.

MR. THEODORE F. HATCH: * In Tennessee there are quite a number of interesting problems, especially in the western part of the State, where almost every water supply contains iron combined with sulphur, and practically no two receive the same treatment. A study was made of the depth to which iron extended and an attempt was made to correlate this with the geologic conditions. In one section, with the help of the geologists, we were able to predict the proper depth to which to go to get rid of iron. It was done successfully by going down below hardpan and drawing water from the lower depth. The iron content was reduced so that no treatment was necessary. It was very interesting to see the relationship between the geological structure and depth of the various strata and the iron content. One well was run down about 500 feet and cleared up the situation successfully.

MR. PIERCE: I have been checking up on some water softeners through the Middle West and called on a laundryman, who explained, "I want to warn you to look out for iron before you put in softeners. Some three years ago we received complaints that people were getting iron spots on their clothes. They began sending them back to us. The master mechanic decided to renew the pipes in the building in order to get rid of the rust. We spent several hundreds of dollars renewing the water pipes, but it was not long before we had more complaints. We began losing business rapidly until finally we decided that the only solution was to install our own iron removal plant."

MR. DORR: † When the iron content gets high enough to cause complaints, what is the cost of remedying the situation?

MR. KINGSBURY: I think Mr. Bogren brought out the fact that one method of treatment may be applicable in one case and a different one in another case. It all depends on the kind of plant you decide to

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install. It is my impression that iron removal plants are not very expensive. Around here the most common method is aeration and subsequent filtration through coke and then sand filtration, but from some experiments that I have followed it appeared that the iron was almost entirely removed by aeration in coke filters and that possibly the sand filters in that case were not particularly useful. Sand filters can be used to good advantage for the removal of manganese. Most of the manganese at Lowell is taken out in the sand filters; very little in the coke. A plant might range all the way from aeration with subsequent sedimentation to aeration, coke filters and sand filtration. That might, of course, be expensive, but a great deal of ingenuity is being applied to those problems, and I do not think that the cost of such plants is high, especially if you can do it with just aeration and a little coke.

MR. FALES: A lot can be done with just plain aeration.

MR. KINGSBURY: A good deal, if the water is susceptible to it. I learned one thing from Dr. Nasmith when he was here. He called attention to the fact that his experiments had shown that you cannot predict in color removal, for instance, with one water what would happen with another. That also is true with respect to iron. My experience has shown that the iron we have found in Massachusetts ground waters generally lends itself readily to aeration and filtration through coke and sand filters.

MR. HOWARD: I have wondered at times whether increasing the wells in the well field where the iron content had become high, in order to reduce the amount of iron in parts per million in the water, and pumping at the same rate — if it was a matter of dilution by putting in more wells, thus reducing the quantity of iron, or if it was the reduction in the rate of pumping per well. I think it has been the experience of many that if you have a well field, and for some purpose, perhaps a fire, two pumps are put on the same well, thus increasing the rate of pumping, the iron content will increase and stay up. If that is so it would seem as if the reduction by driving more wells is due more to dilution than overcoming the trouble by reduction in the rate of pumping per well. I wonder whether others have had some experience in this connection.

MR. KINGSBURY: I think that might logically happen. I know recently of one supply in Massachusetts where they have gone over all the wells and washed them out. They found around each well considerable iron that came in when they started pumping again. Whether additional wells in that particular well field would help is questionable. Perhaps they have spoiled the well field by drawing too heavily from it until they have impregnated the field with organic matter, and it may

take some time to overcome that difficulty even if they should go back to a lower rate of pumping.

PROF. THOMAS R. CAMP: * I would like to ask the original speaker what falling off in the iron content was experienced with increase in the number of wells. Is there any relationship between decrease in the rate of drawing from wells and decrease in the iron content?

MR. BELKNAP: At North Chelmsford, when additional wells were driven, they put in half as many as the original installation. I do not know the amount of reduction, but it was sufficient to stop complaints from the consumers without installing a deferrization plant.

PROFESSOR FAIR: When you speak of increasing the well field, do you mean placing wells in between the other wells or extending the well field out?

MR. BELKNAP: Extending the field from the original wells.

PROFESSOR FAIR: Then it is quite possible, if you go in the right direction, you will avoid the source of iron, but if you go in the wrong direction you will get right into it. I can't quite see how you get reduction in iron content due to increasing the wells unless you extend the well field.

MR. HOWARD: I think in all cases I know they have extended the line of the wells rather than driving in between the original wells. You may be getting water in the same condition as in your original field.

PROFESSOR FAIR: But you get the water from a different source.

MR. HOWARD: That is true, but of a quality similar to that which you obtained from the main wells before you extended the field. There is every chance, as illustrated at Provincetown, that by extending the wells you will get conditions approaching the condition of the original field. In future years they will probably get in the same condition as the present field. It seems to me to be largely a matter of dilution.

PROFESSOR CAMP: Has anything been done to try to make the ground water level lower progressively?

MR. PIERCE: Are these wells in sand or in gravel, or both?

MR. KINGSBURY: It seems reasonable that part of the advantage in additional wells may be to draw in water from a new source less likely to be the cause of iron trouble.

MR. HARRISON P. EDDY, JR.: † But where the same wells go bad after a short time it doesn't seem as if the change in the source were permanently different.

MR. HOWARD: I might add that in Provincetown if you take the

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rate of increase of iron in the water from the original installation, and then after the additional wells were put in, the rate is about the same.

MR. EDDY, JR.: Can you predict when the new wells will reach a certain iron content?

MR. HOWARD: Yes.

MR. DOANE: I can give an illustration on a very small scale of how quickly the character of a water can change with respect to iron. At a place near Orleans, on the Cape, they tried to get a well so it would come up in a certain part of the house. They drove a well and couldn't get any water that wasn't full of iron. There was a heavy precipitate of iron from it. Over on the other side of the house they drove another well 35 or 40 feet deep and they got nice clear water with no sign of iron. Of course, that is only domestic service and not typical of what you would get with a field of wells, but it shows how quickly the character of a water can change in a short distance. That has continued for years, just that same difference between the two waters on different sides of that house.

MR. KINGSBURY: I have in mind the supply at Chatham. There was a pond there and they started to drive wells on two or three sides of it. When the wells reached a certain depth one could almost predict they would get into a stratum that would yield a very high content of iron. There was a light cover of earth over sand, and the bottom of the pond was perfectly clean white sand, and it didn't seem as if there could be a great deal of organic matter there, but it must have been there in the form of some earlier growth that had been covered up by the blown sand.

MR. PIERCE: Could you drill through it?

MR. KINGSBURY: Yes, but there was nothing down below it but boulders. They have a filter gallery there now, which is in the relatively shallow top stratum.

MR. PIERCE: Could you get down below water containing iron and case it off?

MR. BOGREN: With regard to the discussion a few minutes ago, as to why increasing the well field causes decrease in the iron content, I would like to ask the opinion of the other members if it is not possible that by installing a larger number of wells, and thereby decreasing the draft on each well, you might remove the cause of some change in the chemical character of the water by normalizing the pressure on the water. In the case of an over worked well you might have a condition similar to working a rapid sand filter under excessive loss of head; by installing additional wells you decrease the draft on each well and thereby

decrease the change in pressure at the point of intake. You might have bicarbonates releasing their CO_2 under conditions of excessive draft, which you wouldn't have if the difference in pressure were not so great. I would like an opinion on that.

MR. KINGSBURY: That is getting into physics. I think Professor Camp can talk on that.

PROFESSOR CAMP: It seems to me that by increasing the well field you are raising the water table at each well, and the CO_2 near the surface gets further away from where you are drawing water into the well. The same thing occurs if you drive the well deeper. You get less CO_2 and so less dissolved iron.

MR. KINGSBURY: You mean that it is more possible to get re-aeration being near the surface of the ground.

PROFESSOR CAMP: Near the surface of the ground you get more CO_2 than in the lower water table.

MR. KINGSBURY: Following Mr. Bogren's idea, I suppose if you increase your slope of ground water going toward the well, the slope is very much increased as you approach the well point, and in that particular area, within 5 or 6 feet of the well, where the slope is considerable, would that set up any peculiar surface tension occurrence that might influence the oxygen content or the CO_2 content?

MR. HOWARD: In the case of one water supply at Yarmouth the rate of pumping was increased and there was apparently no depression in the ground water level at all. We have made investigations from time to time and can't detect any depression in the ground water level there. The water seems to come in at as great a rate as we can pump it. In that case, if it is due to the influence of surface water, there ought to be no increase in iron content of the water as the years go on.

PROFESSOR CAMP: At what rate are you pumping the wells?

MR. HOWARD: There are 14 wells which are being pumped at the rate of $16\frac{2}{3}$ gallons per minute per well. We have pumped at higher rates without any appreciable lowering of the ground water level.

MR. KINGSBURY: The stratum is almost uniform, isn't it?

MR. HOWARD: It is.

MR. KINGSBURY: I might mention that in searching for a water supply for Yarmouth they tried at several different points in the town, and at every site except the final one the water found was very high in iron.

MR. EDDY, JR.: I understand that one of the speakers is a member of the Section and one isn't a member of the Section. I suggest a rising vote of thanks to the member who is not a member of the Section.

HOWARD E. BAILEY (by letter):* Surface indications cannot be relied upon to determine whether or not a proposed ground water supply will contain iron. Substantially iron-free water has sometimes been obtained in swampy regions where indications of a potable supply were most unpromising, and conversely, a grass-covered, sandy plain bordering a stream may cover a stratum of material which yields water freely and yet contains sufficient iron to make the development of such a source impracticable. Moreover, the fact that an excess of iron is indicated by a test well in a certain locality does not imply that an excellent water may not be obtained 50 or 100 feet away.

An instance of this kind is found at Weston, Massachusetts, in the Kendal Green well field. The original 12 wells, 38 to 40 feet deep, were driven along Stony Brook in 1911, in a small cove measuring about 50 by 100 feet. Water from these wells is obtained at a rate of about 10 gallons per minute per well, and has an iron content of 0.1 p. p. m., or less, varying only slightly from year to year. In 1929, 19 test wells were driven all over adjacent areas within 1,000 feet of the existing wells, in an attempt to locate an additional supply of water. The amounts of iron in the water of these wells, presented in Table 1, together with the distance from the well field, indicates that in very few cases did the quality even approach that of the well field. Just why the iron-free water should lie in this small cove remains a mystery.

TABLE 1.—IRON IN WATER OF TEST WELLS AT WESTON, MASSACHUSETTS, 1929

TEST WELL NUMBER	Iron (Parts per Million)	Distance from Kendal Green Well Field (Iron = 0.10 p. p. m.) (Feet)
1	2.7	180
2	0.2-3.5	120
8	0.6	80
9	0.3-2.7	160
10	3.7-6.0	170
11	1.0	80
12	4.0-15.0	280
15	0.5-2.2	340
16	2.2	1,100
17	0.1	1,300
18	0.3-2.4	40
19	4.0	110

* Assistant Engineer, Metcalf & Eddy, Boston, Massachusetts.

The amount of iron in well water may vary with the depth, as was demonstrated by these test wells. The results for samples taken from the test wells at different depths are given in Table 2. From this wide variation it may be assumed that raising or lowering the well strainer might improve the supply.

TABLE 2.—IRON CONTENT OF WATER AT DIFFERENT DEPTHS FROM TEST WELLS AT WESTON, MASSACHUSETTS, 1929

TEST WELL NUMBER	IRON (PARTS PER MILLION) AT DIFFERENT DEPTHS BELOW GROUND SURFACE				
	Twenty Feet	Twenty-five Feet	Thirty Feet	Thirty-five Feet	Forty Feet
2	—	0.2	2.2	—	3.5
9	—	0.3	2.7	—	—
10	—	3.7	—	6.0	—
12	15.0	4.0	—	—	—
15	—	0.5	2.2	—	—
18	2.4	—	0.3	—	—

An instance of the application of this method has just been demonstrated at Woburn, Massachusetts, in a gravel-wall type of well on the shore of Horn Pond. While sinking the well, a stratum of black cemented sand and gravel about 6 inches thick was encountered 30 feet below the ground surface. Upon analysis the black material was found to consist mainly of iron. In developing the well, the casing was sealed off at a point a few feet below this stratum, and a 30-foot strainer with gravel wall installed below. Pumping at a rate of over 1,000 gallons per minute from this well yielded an excellent water with an iron content of less than 0.1 p. p. m.

Iron may occur in different forms in the same locality, as evidenced at the Soucook River well field at Concord, New Hampshire. A group of test wells on the west flood plain of the river yielded a water whose iron content was 1.30 p. p. m. An experimental iron removal plant, with provision for aeration, coke filtration, sedimentation and rapid sand filtration, and having a capacity of 18 gallons per minute, was erected to test the treatment of this water. The effluent from the plant at all times of normal operation had an iron content of less than 0.1 p. p. m. A portion of the iron settled out on the coke pre-filters, a portion

was deposited in the sedimentation tank which provided a four-hour detention period, and the remainder was caught on the rapid sand filter.

Two of these test wells were within 40 feet of the Soucook River, the water of which had an average iron content of about 0.35 p. p. m., with a color of 30 p. p. m. It was thought that the same treatment without the addition of chemicals could be applied to the river water with equal success in emergencies. The effluent of the treatment plant, however, when treating river water, still had an iron content of 0.35 p. p. m., this treatment apparently having no effect on the iron in solution in the river water. It is probable that the iron in the river water was combined with organic acids in such a way that it would not precipitate upon standing after aeration.

Test wells on the east side of the river only 1,000 feet distant yielded a substantially iron-free water when pumped at the rate of 10 gallons per minute per well. This field has been developed with 150 wells yielding approximately 1,000 gallons per minute, and these have been in operation for about nine months, with a satisfactory water having an iron content below 0.1 p. p. m.

ROBERT SPURR WESTON: The authors have done a great service in assembling the data regarding the occurrence of iron in Massachusetts ground waters and in discussing the peculiarities of wells in the glacial drift, where it seems as if one man's judgment regarding water to be won from wells is about as good as another's. This is not a true statement, of course, but the inconsistencies make one sure that the laws of the occurrence of iron in Massachusetts are far from being exactly known.

It is certain, however, that water from near deposits of peat and bog-iron is better where the draft is light. It is also true that wells can become spoiled, sometimes semi-permanently, just as wells near salt marshes have to be abandoned when a heavy draft causes an influx of chlorides. In these cases resting is usually of little service.

It is unfortunate that while, as a rough rule, the coarsest gravels and consequently the largest yields of ground water are near streams, the largest concentrations of iron and manganese are there also.

The authors mentioned the removal of manganese by the filters at Lowell, and the following data regarding the occurrence of manganese in certain waters may be worth recording with this paper:

MANGANESE IN GROUND WATERS

LOCALITY	Manganese (p. p. m.)
Amesbury, Mass.	0.30
Babylon, N. Y.	0.07
Barnstable, Mass.*	0.03
Bayshore, N. Y.	0.37
Billerica, Mass.	1.60
Bjornstop, Sweden	3.4 to 53.4
Breslau, Germany	Trace to 220
Brookline, Mass. (av.)	0.41
Calverton, N. Y.	0.30
Cohasset, Mass.	0.15 to 0.40
Halle, Germany	1.50
Kingston, Mass.*	0.05
McKees Rocks, Pa. (Pittsburgh Suburban Water Company)	1.0 to 4.0
Medway, Mass.*	0.05
Middleborough, Mass. (av.)	0.67
Patchogue, N. Y.	0.20
Reading, Mass.	0.004 to 0.56
Stettin, Germany	5.22
Superior, Wis.	0.12

The results of manganese determination are relatively few, probably because of the greater difficulty of the chemical work as compared with the iron determination. An account of the occurrence of manganese has been published elsewhere.†

Manganese is a near relative of iron but more difficult to remove. It interferes with the removal of iron.

The relation of iron and free ammonia is important, as the authors have stated. The relation between iron and oxygen consumed is also important as a measure of the organic matter which, when combined with iron, is so difficult to remove by oxidation, contact and straining.

Deferrization is one of the simplest of purification processes; it is difficult to understand why it is so generally avoided. It is not costly, high rates of filtration being practicable and the use of chemicals rare.

The amount of iron is an important factor in the deferrization process, when high, simple aeration and filtration are often adequate. Recent experience at Amesbury illustrates this. This plant consisted

* Results by courtesy of Mr. H. W. Clark, Chief Chemist, Massachusetts Department of Public Health.

† Manganese in Water: Its Occurrence and Removal, by R. S. Weston. Journal of American Water Works Association, Vol. 23, pp. 1272 *et seq.*

of aerators, coke contact aerators 6 feet thick, and sand filters. In the beginning of operation all these were necessary, but with the increase in raw-water iron it has been found that the coke aerator may be reduced to 3 feet in thickness without impairing results. In fact, the part of the plant operating with the thinner coke aerator is removing over 99.9 per cent of the iron.

The present tendency in deferrization plants is toward the upward-flow type of contact aerator, as used by Pirnie at Long Beach.* This is because of saving in head, greater ease in cleaning, and a longer period of contact.

If the water be properly treated by aeration, contact or chemical treatment, or by a combination thereof, the type of filter is relatively unimportant. High rates may be employed. Slow filters are safer where manganese is a factor.

In closing, may the service which the authors have performed be again commended.

* Water Works Practice, p. 249.

BOSTON SOCIETY OF CIVIL ENGINEERS— ACTIVITIES AND PURPOSES

HEADQUARTERS, 715 TREMONT TEMPLE, BOSTON, MASS.

(Prepared by Committee on Membership and Publicity, 1931-1932*)

THE SOCIETY

THE Boston Society of Civil Engineers is the oldest engineering society in the United States. It was organized in 1848 and incorporated in 1851 "for the purpose of promoting science and instruction in the department of Civil Engineering."

During the eighty odd years of its life, the place of the Society in the community has become well established, and it continues to number on its roster many engineers of note, not only in New England, but also in other parts of the United States and abroad, — men who have actively and prominently contributed to the tremendous engineering and industrial advances of the period since the founding of the Society. The present membership is over 1,000.

ORGANIZATION

The organization of the Society is conventional. The President, Secretary and Treasurer are elected annually for one year. One Vice-President and two Directors are elected annually for two years. The administration of Society affairs is vested largely in the Board of Government, composed of the officers and the three latest Past Presidents. Various standing and special committees are chosen from the membership. The names of current officers are listed on the inside front cover of each issue of the JOURNAL of the Society.

THE SECTIONS

The Sanitary Section, the Designers Section, the Northeastern University Section, and the Highway Section have been established in the order named, and are in active and successful operation, conducting independent meetings at stated intervals.

* Reprints will be available for those desiring them for the purpose of interesting prospective new members.

MEETINGS

The main Society meets regularly on the fourth Wednesday in January and the third Wednesday of other months except July and August. The speakers and subjects to be presented are chosen with the object of providing attractions that will appeal to every member. The Sections meet as follows:

Sanitary Section, first Wednesday of March, June, October and December.

Designers Section, second Wednesday of October to May, inclusive.

Northeastern University Section, first Friday of every five-week school period.

Highway Section, fourth Wednesday of February, May, September and November.

The Sections of the Society create opportunities for members of like interest to gather and exchange ideas through the discussion of papers dealing with those matters which particularly interest them and which may not be broad enough in their scope to be of general interest to the membership at large.

Technical trips are made, occasionally, to local projects of major engineering interest, and all who are able to go find pleasure and profit in these opportunities to view and discuss the work of others.

HEADQUARTERS

The headquarters of the Society are located at 715 Tremont Temple, 88 Tremont Street, Boston, Mass. These rooms are also used as headquarters by the Engineering Societies of Boston, an affiliation of thirteen member societies with the purpose of encouraging closer personal and professional contact between the several groups. At the present time the member societies are as follows: Boston Society of Civil Engineers; New England Water Works Association; Plant Engineers' Club; Boston Section, American Institute of Electrical Engineers; Boston Section, American Society of Mechanical Engineers; Northeastern Section, American Society of Civil Engineers; Boston Section, American Institute of Mining and Metallurgical Engineers; Massachusetts Chapter, American Society of Heating and Ventilating Engineers; Boston Chapter, American Association of Engineers; Boston Section, American Welding Society; New England Section, Illuminating Engineering Society; Massachusetts State Engineers' Association, Inc.; Boston Section, The American Society of Refrigerating Engineers.

REQUIREMENTS FOR ADMISSION

The requirements for admission to the Boston Society of Civil Engineers, while less severe than those of the National Societies, are sufficiently specific to lend dignity to membership. In the accompanying tabulation are summarized the requirements for admission, the entrance fees, and the dues for the several grades of membership.

Grade	GENERAL REQUIREMENT	Age Minimum	Entrance Fee	ANNUAL DUES	
				Resident	Non-Resident
Member	Civil, mechanical, mining or electrical engineers or members of other technical professions	24 yrs.	\$10.00	\$10.00	\$6.00
Honorary Member	Men of eminent scientific attainment whom the Society shall deem worthy	—	—	—	—
Junior	In active practice of engineering or students in or graduates from recognized engineering school . .	18 yrs.*	5.00	5.00	4.00
Associate	Others interested in the objects of the Society	—	10.00	10.00	6.00

COMMITTEE ACTIVITIES

A number of standing and special committees carry on the routine work of the Society and conduct research upon such special subjects as may be suggested from time to time. Work on appropriate committees can usually be found for those indicating their interest to the Secretary.

THE JOURNAL

The official publication is the "Journal of the Boston Society of Civil Engineers." The JOURNAL is issued monthly, except July and August, and is free to all members. It contains transcripts of papers and discussions and other matters of interest and value to the membership. Binding can be arranged for annually through headquarters at nominal cost.

* Membership ceases at age of 26 years unless transferred to a higher grade.

LIBRARY AND READING ROOM

The library and reading rooms are at headquarters and are open daily, except Saturdays, Sundays and holidays, from 9 until 5. The Saturday hours are from 9 until 1, except that during July and August the rooms are closed all day. The library contains files of engineering periodicals and many shelves of reference books. Members of the Society are also entitled to library and reading room privileges in numerous other engineering libraries in cities all over the country. Boston Public Library privileges may also be arranged for members not already entitled to them as citizens of Boston.

BADGES

Badges may be secured by members upon application to the Secretary. They are of 14-karat gold, mounted either as an ordinary pin or as a watch charm. The margin and letters are in gold and the ground is of maroon enamel.



MEDALS, PRIZES AND SCHOLARSHIPS

The FitzGerald medal, endowed in 1910 by the late Desmond FitzGerald, is awarded annually to a member of the Society for a paper of outstanding merit.

Since 1924 a prize consisting of books to the value of \$15 has been awarded annually by the Board of Government for the presentation and publication of a paper of special excellence in each of the Sections by one of its members. Also authors of papers that have been particularly noteworthy and commendable are rewarded by the presentation of copies of Clemens Herschel's "Frontinus and the Water Supply of the City of Rome." This award is the gift of the author, who also bequeathed a fund, the income of which is to be used to continue this or a similar award.

The Tinkham Memorial Fund provides for an annual scholarship of about \$125 to assist a worthy student of high standing in civil engineering at the Massachusetts Institute of Technology.

The Freeman Fund, the gift of John R. Freeman, was established in 1925 for the purpose of encouraging young engineers, and particularly for study in hydraulic problems and research, and has been used largely to provide for travelling scholarships for study and research in European hydraulic laboratories.

In 1931 there was appropriated from the income of a bequest by Desmond FitzGerald \$100 as a scholarship for a worthy student in civil engineering at Northeastern University. It is hoped that circumstances will permit the continuation of this scholarship.

SOCIAL ACTIVITIES

Social activities have, in recent years, become an important factor in the life of the Society. An active committee is charged with the responsibility of providing an atmosphere of sociability. This has been accomplished by buffet suppers served before the regular Society meetings, by summer outings to seaside resort or country club, and by smoker and banquet at the annual meeting, thus providing opportunities for members to meet old friends and to make new ones.

EMPLOYMENT SERVICE

Those seeking employment may be registered upon application at headquarters, and their qualifications brought to the attention of inquiring employers. An effort is made to keep the lists up-to-date so that they may be of maximum usefulness to both applicant and employer.

ADVANTAGES OF MEMBERSHIP

The realization of tangible benefits from membership in the Boston Society of Civil Engineers depends largely upon the efforts of the individual. While mere membership without activity lends a certain amount of prestige, personal return is to a great extent in proportion to a member's service in the Society. New members will find it easy to make new friends and to take an active part in the operation of the Society. There are excellent opportunities for broadening acquaintance through attendance at the meetings and social functions. The presentation of papers, contribution to discussions, and service on committees not only help to advance the engineering profession as a whole, but also reward the individual with a measure of professional prominence.

OF GENERAL INTEREST

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Designers Section

JANUARY 13, 1932. — The regular meeting of the Designers Section was held in the rooms of the Engineering Societies of Boston and was called to order at 6.10 P.M. by the Chairman, Erwin Harsch.

The minutes of the December meeting were read and approved.

Attention was called to the date of the annual meeting on February 9, 1932.

A paper entitled the "Physical Properties of Clay" was very ably presented by Mr. Arthur Casagrande, who is em-

ployed by the United States Bureau of Public Roads for carrying on research in the field of soils at Massachusetts Institute of Technology. Mr. Casagrande showed by means of lantern slides the graphical diagrams indicating the results of his laboratory tests, and also many illustrations of the action of clay as a foundation material.

Mr. Casagrande's talk was followed by a general discussion in which many took part.

Sixty-two members and guests were present.

The meeting adjourned at 8.25 P.M.

HERMAN G. DRESSER, *Clerk.*

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

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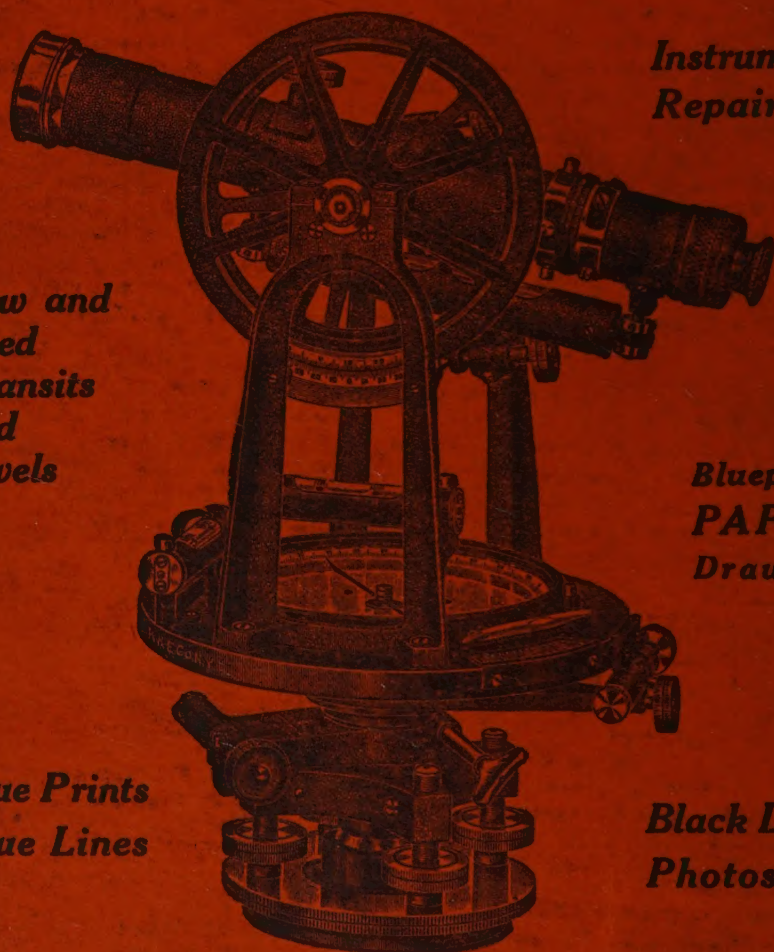
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